Buying Safe Cables

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Photovoltaic (PV) modules will supply energy for thirty years or more when illuminated by the sun. Cables and conductors used in PV systems need to be able to carry that PV-supplied energy safely for thirty years or more without deterioration.

Numerous types of conductors, wire, and cables are widely available from a number of sources with a bewildering array of labels and prices. How do we determine that a particular cable is safe for use in a particular application, and that it will remain safe over the many years that our renewable energy systems will be producing energy?

In previous *Code Corner* columns, we have covered the conductor type markings (USE-2, NM, RHW-2, THW, etc.) required on cables to be used in various locations in a PV system. We have discussed the environmental conditions that require type markings for conditions such as exposure to sunlight, temperatures, and moisture.

Unfortunately, there are many sources of electrical cables that do not have these markings. These include auto parts stores, hardware stores, building supply stores, and welding supply shops, among others. Many of these cables do not have any marks or labeling that ensure that they have been tested and evaluated for safety in any application.

To ensure the greatest probability of buying and using safe, durable conductors that meet the requirements of the *National Electrical Code (NEC),* you should look for cables that have at least the following markings or labels. First, the type marking (USE-2, RHW-2, THWN-2, etc.) should be on the cable, and that type marking should be appropriate for the particular application, such as module interconnections or battery-to-inverter cables.

The second mark should be the mark of a nationally recognized testing laboratory such as UL (Underwriters Laboratories). This indicates that the cable has undergone extensive testing for the application, and has been "listed" for compliance with the appropriate UL standard for that type of cable. The *NEC* requires that all equipment used in electrical systems be listed. UL is the only laboratory that is recognized and accepted throughout the United States for testing and marking cables. Note that cables bearing the CSA (Canadian) or CE (European) marks must also have the UL mark to comply with U.S. requirements.

UL Standards for Cables

Underwriters Laboratory has two major functions in the electrical energy industry in the United States. The first function is to write, coordinate, and publish safety standards. The second function is to test and evaluate materials and equipment against those standards. A safety standard is a document that details all of the tests and the results of those tests that a particular type of cable must meet before it can be listed as complying with the standard.

For example, UL Standard 44 for "rubber-insulated wires and cables" was first published in 1917, and has had fifteen major revisions since then. The latest edition was published in 1999 and is now titled "Thermoset-Insulated Wires and Cables." This standard covers conductor types such as RHW, THW, XHHW-2, and similar cables that are acceptable for use as battery cables in a PV system. Numerous companies and other agencies that design, manufacture, sell, install, and inspect cables are involved in keeping the standard current.

This standard is more than seventy pages long and is updated periodically. It is completely revised every few years as the technologies for making, using, and testing cables change. In addition to requirements on what types of rubber and synthetic rubber are required to make the cables, numerous tests are included in the standard. These tests are used to verify the quality, durability, and safety of the cables.

Each UL standard references other UL standards that must also be met. For cables, there are additional standards that establish requirements for the insulation material and the copper used in cables. Here are some of the basic tests, each of which is spelled out in specific detail in the standard:

- Dielectric voltage—withstand test in water
- Insulation resistance in water at rated temperature
- Insulation tests in air at rated temperature
- Alternative spark testing
- Mechanical water absorption test

- Capacitance and specific inductive capacity tests
- Tests for stability factor
- Cold-bend test
- Deformation test
- Crushing tests
- Dielectric breakdown after glancing impact
- Dielectric breakdown after scoring
- Horizontal-specimen flame test
- Vertical wire flame test
- Sunlight-resistance test (tray cables)
- Oil resistance
- Gasoline resistance

The standard details each test, how it will be conducted, and what results are required for passing.

In *HP80,* a report was presented on testing welding cable for acid resistance. Since all rubber and plastic insulated conductors are considered to be inherently acid-resistant in electrical applications, no test is specified for acid resistance in the UL standard. The inadvertent inclusion of the term "acid-resistant" in Section 690-74 in the 1996 *NEC* was corrected in the 1999 *NEC,* and this term no longer appears.

Testing to the Standard

The standard is used by nationally recognized testing laboratories to test the cables. UL at the present time is the only laboratory testing, listing, and labeling cables used in electrical power systems complying with the *NEC.* This is the second function that UL has with respect to cable markings.

A nationally recognized testing laboratory is one that has gone through a lengthy evaluation process conducted by special certification agencies that ensure that the lab has sufficient personnel with the appropriate educational backgrounds and experience, and sufficient test and evaluation equipment to properly perform the required tests. Test equipment must be calibrated against calibration standards directly traceable to the National Institute of Standards and Technology (previously, the National Bureau of Standards).

A cable is submitted to UL for testing against the standard. UL tests the cable, and, if it passes all of the tests in the standard, UL allows the manufacturer to use the UL mark (the letters "UL" in a circle) on the cable indicating that it is a listed product. UL also visits the manufacturer's facility and determines that the equipment and processes used to make the cable are of sufficient quality and consistency to ensure that each production run of the cable has uniform properties (meets the standard).

However, the testing does not end there. Any time there is a change in the materials used in the cable, or in the way in which the cable is made, the manufacturer must notify UL and resubmit the modified cable for evaluation and possible retesting.

Every three months, UL visits the cable manufacturer as part of their followup service. They verify that the materials and production processes are still producing the same cable that was originally tested. UL may pull random samples of cable from the production line or the warehouse and retest them at any point.

To further establish the continuing quality of any listed cable in this highly competitive industry, other cable manufacturers test samples of their competitors' cables, and protest to UL if the listed cables do not meet the standard in any way.

Make an Informed Decision.

Yes, you can purchase unmarked or improperly marked wires and cables at electronic stores, hardware stores, the welding shop, and auto supply stores. They may work quite well in a PV system. But then again, they may not.

How are you to know that a piece of unmarked (no type mark, no listing mark) cable x that you bought yesterday will perform the same as a similar piece of unmarked cable that you bought at the same store a year ago? Is cable x bought in Arizona the same as cable x bought in California? Will either of these cables withstand the test of time? Did the manufacturer cut costs by making the insulation a little thinner? Did the manufacturer change insulation materials to a type that might save a few pennies, but might crack or catch on fire more easily? Were costs reduced by accepting copper with more impurities that might become brittle or have a higher resistance?

The use of a properly type-marked, UL-listed cable ensures that most of these uncertainties are eliminated. With reliable PV modules producing electricity for thirty or more years, it seems prudent to buy cables that have been thoroughly examined and tested by trained, experienced personnel. The system installer and owner will then not have to worry about the uncertainties of using unmarked cables.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC,* feel free to call, fax, email, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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